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A review of hooking mortality rates for marine recreational coho and chinook salmon fisheries in British Columbia.

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Abstract

This review examines hooking mortality rates for marine recreational coho and chinook salmon fisheries in British Columbia. Hooking mortality results from non-harvest fishing and refers to the proportion of fish dying after being captured and then released (Muoneke and Childress 1994). Currently, coastwide hooking mortality rates are set at 10% for adult coho and 15% for adult chinook, independent of the gear or method of presentation used (Terry Gjernes, Fisheries and Oceans Canada, personal communication). These values come from several studies conducted in the late 1980's and early 1990's in Washington State (NRC 1991) and British Columbia (Gjernes 1990, unpublished), where active trolling of both artificial and natural baits was the primary method used to catch fish.

In recent years, the British Columbia tidal waters recreational fishery has declined overall but has expanded in the more remote areas, particularly with respect to both charter and lodge-based operations. Coincident with this expansion has been local preference and specialization in the types of gear being fished and the methods used for their presentation. For example, variations in "mooching" techniques (e.g. drift mooching, live mooching, motor mooching, etc) and "trolling" techniques (e.g. bucktailing, downrigger trolling, wire line trolling etc) are now widespread along the British Columbia coast. Given that hooking mortality is closely related to where hooks are located in fish (Muoneke and Childress 1994), and because different gears and methods of presentation result in salmon being hooked in different ways (NRC 1998), concern exists that the application of common hooking mortality rates to all gear types and fisheries in British Columbia may not be appropriate.

The purpose of this report is to outline current knowledge regarding hooking mortality as it relates to coho and chinook salmon captured in marine recreational fisheries in British Columbia. This review is organised into five sections. The first section summarises the scope of marine recreational fisheries within B.C. coastal waters in terms of locations fished, and fishing methods used. The second section discusses hooking mortality rate estimation and the factors known to affect hooking mortality for fish captured in sport fisheries. The third section summarises current knowledge regarding the range of hook and release mortalities for coho and chinook using different gears and methods from recent studies conducted in British Columbia, Washington, Oregon, and California. The fourth section provides an overview of recent reviews of available hooking mortality information conducted by several fisheries agencies. Finally, the fifth section (discussion and recommendations) discusses the implication of the available data and outlines priority information gaps for stock assessment consideration.

Résumé

Le présent examen traite de la mortalité par capture à l'hameçon des saumons coho et quinnat faisant l'objet d'une pêche récréative en Colombie-Britannique. Cette mortalité est le résultat de la pêche avec rejet et correspond à la proportion de poissons qui meurent après avoir été remis à l'eau (Muoneke et Childress, 1994). Elle est actuellement fixée à 10 % pour les cohos adultes et à 15 % pour les quinnats adultes, cela indépendamment de l'engin ou du mode de présentation utilisés (Terry Gjernes, Pêches et Océans Canada, comm. pers.). Ces valeurs ont été tirées de diverses études réalisées à la fin des années 1980 et au début des années 1990 dans l'état du Washington (NRC, 1991) et en Colombie-Britannique (Gjernes, 1990, inédit), où la pêche à la traîne à l'aide d'appâts artificiels et naturels constituait la principale méthode de pêche.

Au cours des dernières années, un déclin général de la pêche récréative dans les zones de marée de la Colombie-Britannique, mais cette pêche s'est accrue dans les zones plus éloignées, notamment la pêche à partir de bateaux de location ou de pourvoiries. Cette expansion s'est accompagnée de préférences et de spécialisations locales quant aux types d'engins et à leurs modes de présentation. Par exemple, des variations de techniques de pêche à la cuiller, et de techniques de pêche à la traîne sont maintenant généralisées le long de la côte de la Colombie-Britannique. Comme la mortalité par capture à l'hameçon est fortement liée à l'endroit où l'hameçon est ferré (Muoneke et Childress, 1994) et que des engins ou des méthodes de présentation différents font que les saumons ne sont pas ferrés aux mêmes endroits (NRC 1998), il y a lieu de craindre que l'application de mêmes taux de mortalité par capture à l'hameçon à tous les types d'engins et de pêches utilisés en Colombie-Britannique ne donne pas de bons résultats.

Le présent rapport a pour objet de présenter les connaissances actuelles en matière de mortalité due à la capture à l'hameçon pour la pêche récréative des saumons coho et quinnat dans les eaux marines de la Colombie-Britannique. L'examen est réparti en cinq parties. La première résume l'étendue de la pêche récréative marine dans les eaux côtières de la Colombie-Britannique et met l'accent sur les zones de pêche et les méthodes utilisées. La deuxième est une discussion de l'estimation de la mortalité due à la capture à l'hameçon et des facteurs connus qui influent sur le taux de mortalité des poissons capturés par les pêcheurs récréatifs. La troisième résume les connaissances actuelles en ce qui a trait à la gamme des taux de mortalité de la pêche par capture et remise à l'eau des saumons coho et quinnat capturés à l'aide de méthodes et d'engins divers, qui ont été déterminées à partir d'études effectuées récemment en Colombie-Britannique, au Washington, en Orégon et en Californie. La quatrième est un résumé d'examens récents des données sur la mortalité due à la capture à l'hameçon qui ont été effectués par divers organismes des pêches. La cinquième et dernière partie (discussion et recommandations) traite des incidences des données disponibles et résume les carences d'informations importantes pour l'évaluation des stocks.

Section 1.0: Scope of Marine Recreational Fisheries in British Columbia

The tidal waters of BC offer a great variety of recreational fishing opportunities for Pacific salmon. While five species are now taken in the fishery, chinook and coho have historically accounted for a great proportion of the catch. This is mainly due to the fact that both species remain in near-shore waters for their entire marine life and are consequently available to recreational fishers for a much longer period than are the other species. Chum, pink and sockeye salmon are frequently more abundant than chinook or coho but spend much of their marine life far offshore and then migrate fairly quickly through coastal waters on their migration to spawning rivers. Consequently they can provide a fairly intense fishing opportunity but only for a relatively short period of time.

Because chinook and coho are accessible to anglers for a long period of time they can be exploited at quite substantial rates in recreational fisheries. On the other hand, the economic benefit from a recreational fishery is a function of effort, not catch. Therefore the goal of recreational salmon fisheries management should be to maximise the effort for a given exploitation rate. Management measures commonly implemented to control the exploitation of salmon are daily (and possession) limits, minimum and, in some cases, maximum size limits and species non-retention regulations. All of these measures result in the requirement to release some salmon that are caught by recreational fishers. These management measures would be of no use unless a substantial proportion of the released fish survived.

Coho and chinook salmon are caught by a variety of recreational fishing techniques but there are two basic methods: trolling and drift fishing (White, 1974). Generally, trolling entails pulling lures or bait behind a boat under power at a speed of about 1 - 2 m/second or even faster in certain situations. Drift fishing usually means fishing with lures or bait from a boat that is stationary (anchored), drifting or being propelled slowly (usually less than 1 m/sec.). Mooching is a specialized version of drift fishing where baited lines are generally kept an angle of 45° or greater with respect to the surface of the water (Straight *in* White, 1974). Where salmon are scattered over a wide area, trolling is usually the preferred technique. Also, inexperienced anglers who have not learned where salmon are likely to be found usually troll. In areas where feeding chinook and coho salmon congregate mooching can be extremely effective. Pacific salmon may also be caught by other techniques including fly fishing. However a great majority of the sport-caught chinook and coho are taken via trolling or motor mooching. On a coast-wide basis, trolling is probably the most common method of recreational salmon fishing.

In the South Coast, trolling is the most popular method from Vancouver to Victoria and Juan de Fuca Strait and up the west coast of Vancouver Island as far as Barkley Sound and Alberni Inlet. A few notable exceptions are Active and Porlier Pass and off the entrance to Nitinat Lake where motor mooching with plug-cut herring is very popular with anglers trying to catch chinook salmon. On the Sunshine Coast mooching with live herring from an anchored boat historically has been the method of choice although trolling is now practised more frequently since salmon have become less abundant. Along the east coast of Vancouver Island trolling is the most commonly practised method although both mooching with herring and drift fishing with jigging lures are also popular. At the northern part of the Strait of Georgia, particularly around Campbell River and at the entrance to Bute Inlet, motor mooching with plug-cut herring is very popular. However, as in other areas of the Strait, with the recent decline in salmon abundance, trolling is becoming more common. Trolling with either lures or bait is also the most common method employed in most areas along the west coast of Vancouver Island, in Johnstone and Queen Charlotte Straits and in the mainland inlets. However in each area, mooching with plug-cut herring is practised by a dedicated group of experienced anglers who know where coho and particularly chinook salmon congregate.

In the Central Coast, motor mooching with plug-cut herring is probably the most popular method of salmon fishing, particularly for chinook. However, trolling is also frequently employed when mooching does not appear to be effective. In areas such as Rivers Inlet and Hakai Pass where lodge-based anglers frequently congregate in one "hot spot", it would be difficult to troll properly so mooching is the method of choice.

A similar situation occurs in the North Coast. Although trolling is quite common in most locations, motor mooching with cut-plug herring is becoming more popular each year. On the Queen Charlotte Islands virtually all the lodge-based anglers employ some form of motor mooching with cut-plug herring.

Over the past two decades various studies have been conducted in order to estimate the mortality of chinook and coho salmon released in recreational fisheries (Gjernes et al.1993, NRC 1991, NRC 1994, NRC 1998, Cox-Rogers 1998, in press). Unfortunately not all of the studies have yet been published so some of the information is not readily available. The work to date has shown that the estimated mortality rate of released Pacific salmon can be quite variable; from about 5 to over 30% in tidal waters. In each of these studies, hooking location was found to be the variable most associated with hooking mortality. Mortality rates are higher when hooks are located deep in the mouth where injury to the various blood vessels and nerves associated with the throat, heart, and gill arch area can occur. Mortality rates are lower when hooks are located in the outer mouth and jaw area, where injury to the throat, heart, and gill arch area is less likely. In general, salmon caught using trolling techniques are often hooked in the outer mouth and jaw area, while salmon caught using mooching techniques are often hooked in the deep mouth and throat or gullet area. Although the results are not conclusive, it appears that chinook and particularly coho salmon released from sport trolling gear may survive at a higher rate than do those caught and released via mooching with natural bait such as herring.

Section 2.0: Estimation of Mortality Rates

Hooking mortality has been evaluated by a) subjective examination of fish condition upon landing b) holding landed fish in special live tanks or net pens and monitoring survivals over a specific time period or c) tagging fish with external, radio or sonic tags and examining relative recovery rates of tagged and released fish (CTC 1997). Most published studies of hooking mortality involve holding fish and monitoring survival over time (Wright 1970, Gjernes 1990, NRC 1991, NRC 1994, NRC 1998, Muoneke and Childress 1994, Cox-Rogers 1998 in press). Because these types of experiments cannot be completely controlled, all of these estimates are subject to potential and unmeasured biases (CTC 1997).

Hooking mortality consists of two major components: landed mortality and non-landed mortality. Landed mortality consists of **immediate mortality**, fish dead at landing; and **delayed mortality**, fish that are alive but die after release from injuries or handling stress (CTC 1997). Delayed mortality can be further separated into short-term mortality, or landed mortality occurring within the 24 hours of capture, and long-term mortality, or landed mortality occurring after 24-96 hours of capture. (Doug McNair, NRC, personal communication). Most studies only involve short-term mortality rates, due to difficulties in holding wild salmon for long periods of time (> 4 days). One recent holding study involving long term mortality of coho salmon captured by commercial fishing gear has raised concern about just how well some salmon species eventually survive the capture and release process (Brent Hargreaves, FOC, personal communication).

Non-landed mortality consists of **drop-off mortality**, fish that escape the gear prior to landing and die because of the encounter, and **associated mortality** or drop-off salmon that die because of subsequent predation, long-term mortality, or regulation non-compliance (CTC 1997). As with long-term delayed mortality, non-landed mortality is difficult to assess, although some agencies do attempt to add some percentage value to landed mortality to account for its affect. Given the difficulty of assessing non-landed mortality, reported hooking mortality rates from holding studies may tend to under-estimate the actual mortality rate associated with some fishing techniques, especially if holding bias is small. The hooking mortality rates currently applied to British Columbia recreational salmon fishery assessments do not incorporate an additional long-term delayed or non-landed mortality component (Terry Gjernes, FOC, personal communication).

Hooking mortality is calculated as a simple proportional estimate from a binomial population:

1) $$\hat{p} = \frac{X}{n}$$

where $\hat{p}$ is the mortality rate estimate, X is the number of fish mortalities, and n is the total number of fish sampled. Using a relationship between the F distribution and the binomial distribution, lower (L_1) and upper (L_2) confidence limits about p can be calculated (Zar 1974):

2) $$L_1 = \frac{X}{X + (n - X + 1) F_{0.05(2),\nu_1,\nu_2}} \quad \text{with} \quad \nu_1 = 2(n - X + 1) \quad \text{and} \quad \nu_2 = 2X$$

3) $$L_2 = \frac{(X+1) F_{0.05(2),\nu_1',\nu_2'}}{n - X + (X+1) F_{0.05(2),\nu_1',\nu_2'}} \quad \text{with} \quad \nu_1' = 2(X+1) \quad \text{and} \quad \nu_2' = 2(n - X)$$

Gear-specific hooking mortality rates can also be used to generate exploitation rates in specific fisheries (E) if information regarding catch (c) boat-day effort (f) encounters (e) percent stock composition (s) and total stock (N) is available:

3) $$f * \frac{c}{f} = e$$

4) $$e * \hat{p} = m \qquad \text{where } \hat{p} = \text{the hooking mortality rate and } m = \text{mortalities}$$

5) $$\frac{m * s}{N} = E$$

Section 2.1: Factors Affecting Hooking Mortality

Studies of hooking mortality in recreational fisheries have shown that fish captured and released by anglers die from two major causes a) lethal injuries caused by the hooks and b) physiological stress associated with being played, landed, and handled (Muoneke and Childress 1994). Physical injury caused by the hook (s) is the most typical cause of death, with bleeding hooking injuries to the deep mouth area (e.g. gill arches, heart, and throat/gullet etc) being the most lethal. However, the extent of lethal injury from hooks located in similar locations within the mouth can vary according to such factors as fishing technique, fish species, fish size, fish behaviour and aggressiveness, food availability, fish abundance, stage of maturity, temperature/season, depth of capture, hook size and type, and angler skill in playing, landing, and releasing (Muoneke and Childress 1994).

For example, Wright (1970), reported coho more prone to physical damage from hooking (commercial troll) than chinook given their propensity to resist gear and fight more readily and aggressively. Large salmon appear able to ingest hooks and baits of a given size more easily than small salmon, which can affect hook location and thus the extent of hooking injury (Doug McNair, NRC, personal communication). Hooks with large gaps tend to cause deeper wounds but small hooks are more easily ingested (Wertheimer et al. 1989, Gjernes et al. 1993). Fish captured and released in warm water have higher mortality rates than fish captured and released in cooler water, and rapid depressurisation can be detrimental to fish unable to make appropriate adjustments to swim bladder air pressure after being hooked at depths and suddenly brought to the surface (Muoneke and Childress 1994).

Recent studies in California indicate that "J" hooks are more easily swallowed by salmon and result in more severe injury than do "circle" hooks (Grover and Palmer-Zwahlen, 1996). Single hooks are usually more easily swallowed than treble hooks, barbless hooks can facilitate release and result in lower mortality rates than barbed hooks, and removal of deeply ingested hooks often increases mortality (Muoneke and Childress 1994), Passive angling techniques (e.g. drift-mooching) are often associated with higher hooking mortality rates for salmon while active angling techniques (e.g. trolling) are often associated with lower hooking mortality rates (NRC 1991, 1998, Allen Grover, CDFG, personal communication).

Fish dying from stress do so as a result of physiological imbalances caused by exertion (Parker and Black 1959). Chronically stressed fish can be more susceptible to disease as a result of a weakened immune system, and sub-lethal stress can be manifested in growth retardation and reproductive impairment (Muoneke and Childress 1994). Stressed fish can also exhibit altered behaviour, which can make them more susceptible to predation upon release (Muoneke and Childress 1994). In British Columbia, coho and chinook salmon are often taken by seals during the process of being played, and its likely that released salmon exhibiting stress are more vulnerable to predation (Terry Gjernes, Fisheries and Oceans Canada, personal communication).

The degree of handling and its affect on mortality depends upon such factors as fish size, angler experience, and the type of terminal gear being used (e.g. light vs heavy tackle, single vs treble hooks, barbed vs barbless etc). Handling can be lengthy if nets are used and fish become entangled or if fish are manipulated and held out of the water for measurement or photographs. In addition to oxygen deprivation when fish are out of the water, excessively handled fish are prone to internal handling injury and can lose scales and mucus, which can lead to eventual infection and death (Muoneke and Childress 1994). The action of removing hooks, especially for deeply embedded hooks, often requires considerable physical manipulation of fish prior to success, which can lead to additional trauma and injury. Cutting the line and leaving deeply embedded hooks in place can reduce hooking mortalities if injuries are not severe (Muoneke and Childress 1994).

Section 3.0: Recreational Salmon Fisheries- Recent Studies

Tables 1 and 2 and Figures 1 and 2 outline recent results for chinook and coho hooking mortality studies that have been conducted in British Columbia, Washington, Oregon, and California over the last decade or so.

British Columbia: Relatively few studies of hooking mortality have been conducted for coho and chinook captured in marine recreational salmon fisheries in British Columbia. Gjernes (1990) observed post-hooking mortality for 152 chinook captured by researchers trolling using flashers and hootchies on downriggers in Georgia Strait. Lures were rigged with two size 4/0 single barbed hooks in tandem, 5 cm apart. The fish caught ranged from 35-80 cm and were held for 24-72 hrs in net pens. Mortality for all fish combined was 9.9%; for fish 35-44 cm, mortality was 12.5%; for fish 45-62 cm, mortality was 8.2%, and for fish >62 cm, mortality was 13.6%. For all size classes, there was no detectable difference in mortality rates between fish hooked on one or both hooks. Hook location was determined to be the most important factor associated with hooking mortality; virtually all of the fish that died had sustained injuries to major blood vessels associated with the gills and heart.

Gjernes (1990) also reported hooking mortality for 83 coho (bluebacks 30-55 cm) captured by volunteers aboard a charter vessel trolling lures and flashers in Southern Georgia Strait on one of three hook configurations: barbed single, barbed treble, and barbless single. The fish were held for a minimum of 24 hours in net pens. The mortality rate for all hooks combined was 7.2%. The mortality rate for fish caught on 1/0 single hooks was only 3.3%. The observed mortality rates for fish caught on barbed and barbless single hooks was essentially the same, although the mortality rate for coho caught on barbed treble hooks was substantially higher (18.2%). As with the other studies, mortality was mainly due to hook injuries involving the gills or major blood vessels associated with them.

Gjernes et al.(1993) reported hooking mortality for sub-legal sport-caught chinook and coho < 30 cm in their first year of ocean residence. Angling was again by volunteers aboard a charter vessel trolling lures and flashers in Southern Georgia Strait with one of four hook configurations: barbed single, barbed treble, barbless single, and barbless treble. The fish were held 6- 30 hrs in 45 gallon holding tanks. In 10 days of fishing 124 sub-legal chinook and 289 sub-legal coho were caught. For all hook types combined, the mortality rate was 30% for chinook and 13.4% for coho. Chinook caught on barbed hooks had a mortality rate of 38.5% compared to 20.3% for chinook caught on barbless hooks. For coho, the mortality rate was essentially the same with barbed single, barbed treble and barbless single hooks (15%-17%). Treble hooks had higher mortality rates than single hooks. Hooking mortality was highest for chinook hooked in the gill arches or blood vessels associated with a gill arch.

Gjernes (1990, page 10), in a summary of his various studies, recommended the following hooking mortality rates be adopted for sport-caught chinook and coho salmon in British Columbia.

	Size	Mortality Rate
Coho	<30 cm	17%
	>30 cm	7-10%
Chinook	<30 cm	40%
	35-45 cm	15%
	45-62 cm	12%
	>60 cm	15%

In 1992 and 1993, Gjernes (unpublished, Terry Gjernes, FOC, personal communication) examined hooking mortality for 100 adult chinook and 100 coho salmon captured on troll mooched cut-plug herring at Langara Island during late August in northern British Columbia. Angling was by volunteers aboard small skiffs troll-mooching with tandem 5/0 and 3/0 barbed hooks. The fish were held in net pens for up to 24 hours. The reported mortality rate was 10% for coho and 15% for chinook. Data regarding hook locations and corresponding incidences of mortality were not available for this review.

Cox-Rogers (1998, in press) observed 242 adult coho (46 – 95 cm) captured on motor mooched cut-plug herring near Work Channel in September 1998. Professional guides and volunteer anglers conducted the fishing. The fish were held for up to 24 hours in live-hold tanks aboard a specially equipped holding vessel. The mean short-term (0 - 24 hr) mortality rate for coho captured on single barbless J hooks (4/0) was 25.5% (17.2% - 35.6%). The mean short-term (0 - 24 hr) mortality rate for coho captured on tandem barbless J hooks (4/0) was 25.7% (18.9% - 33.5%). Hook location was found to be the major factor associated with hooking mortality. A high proportion of the fish that died were hooked in the deep mouth area, where hooking injuries to the various blood vessels and nerves associated with the throat, heart, and gill arches occurred. The mortality rate for coho hooked in the critical deep mouth area was 56.0% (44.7% - 66.9%) compared to only 9.5% (5.5% - 15.3%) for coho hooked in non-critical areas such as the outer mouth and body/head.

Washington: In 1989, NRC (1991) conducted a hooking mortality study of coho and chinook in the Strait of Juan de Fuca. Volunteer anglers and biologists participated in catching the fish from small boats using tandem mooching rigs, 1/0 and 2/0 single-point barbless hooks, and cut-plug herring. A total of 67 chinook ranging in size between 31-101 cm were held from 24-48 hours. The mortality rate was 9%, with most of the fish that died succumbing within the first few hours of landing. Hooking injuries to the gills and heart were the primary causes of death. A total of 146 coho ranging in size from 35-50 cm were held for 24-48 hours. The mortality rate was 6.9%. The data suggested that bleeding caused by the hook wounds was the major cause of death for both species. NRC (1991) noted the large discrepancy between their results and the 26% mortality being rate used at that time by the Pacific Fishery Management Council (PFMC) for Washington, Oregon, and California based sport fisheries.

In 1992 and 1993, NRC (1994a) conducted another hooking mortality study for chinook in Puget Sound. Volunteer anglers fished from charter boats, either mooching cut-plug herring or trolling baits or lures with downriggers. A variety of lures and baits were used: hook types were either single or tandem single-point barbless hooks. Chinook salmon ranged in size from 30-60+ cm and were held for 4 days in net pens. The overall mortality rate was 10.2% for all hook types combined. Injury location was again the variable most associated with mortality. No statistical difference was detected among the various lure and hook types. Fish caught mooching with bait on tandem rigs had a mortality rate of only 4%, well below the overall rate.

Oregon: In 1996 and 1997 NRC (1998) conducted additional research in Oregon on hooking mortality for adult coho (33-78 cm) and adult chinook salmon (30-105 cm) using 9 different gear treatments, each representing a different method/terminal gear combination. The gear treatments included three different mooching combinations for rotating baits (4/0 and 3/0 tandem J hooks, 4/0 single J hooks, 3/0 circle hooks), a "California" mooching technique (with 4/0 circle hooks) where baits are still fished and four different trolling combinations (4/0 and 3/0 hook/baits and lures with and without flashers). The fish were captured by volunteer anglers and held for very short (4 hour) time periods in brood stock tubes. The range of observed mortality rates for the nine different gear treatments was 3%-24% for coho and 0% to 15% for chinook . For coho caught on trolled herring and tandem 4/0 and 3/0 hooks, the mortality rate was only 3%, but rates for seven of the other treatments on which coho were landed were significantly higher, ranging from 13% -24%. For chinook captured on mooched herring and single 3/0 circle hooks, the mortality rate was 0%, as was the mortality rate for chinook captured on trolled herring (with or without flashers), The highest mortality rates for chinook were for the mooching techniques incorporating single 4/0 J hooks (15%) and "California" mooched 4/0 circle hooks (14%). Mooching had a higher mortality than trolling for both species. California mooching was the most lethal method tested (still drift mooching, no boat motion). Hook location was the factor most associated with hooking mortality.

California: Grover (1995a, unpublished) compared "calculated" mortality rates for chinook salmon caught by recreational anglers by a) "California" mooching with anchovy or b) standard trolling techniques off the northern California coast. Anglers fished from commercial charter vessels, and observers categorized the injury location of their catch. Estimated mortality rates were generated by using the mortality rates reported by injury location in Wertheimer et al.(1989). Using this approach, Grover (1995a) calculated that chinook mortality (legal >20 in + sub-legal < 20 in) from 1993-1995 ranged from 11% - 13% for chinook caught on trolling gear and 58% - 73% for chinook caught on mooching. Hooking mortality was high for the mooching technique because of hooks located deep in the mouth and gullet.

Grover (1995b, unpublished) also conducted a hooking mortality study off of Point San Pedro, California, where chinook were captured by "California" mooching and held aboard a large ship-board live well for 24-36 hrs. Of the 217 chinook captured, 67% were hooked in the gut or gill area. Mortality rates were 37% for all hook locations combined, 51% for those fish hooked in the gut area, 7% for those fish hooked in the mouth area, and 46% for those fish hooked in the gill area. Necropsy of surviving gut-hooked fish suggested severe, probably lethal wounds to almost all of these fish; Grover (1995b) estimated that mortality would be 98% for this wound category over a longer holding period.

Grover and Palmer- Zwahlen (1996, unpublished) measured sport drift mooching hook mortality for chinook (20-26 in) for 5/0 and 4/0 J hooks, equivalent sized circle hooks, and blockers (modified J hooks) during four-day tank holding trials off of Point Reyes, California. Baits (anchovy and herring) were placed on the hooks in one of three directions: 1) threaded through the head, 2) pierced through the nose, and 3) threaded through the tail. Ten fishing rods were mooched at a time. 534 chinook were held for 4 days aboard a large shipboard live well, of which 180 survived (66.2% mortality). Circle hooks had a lower gut-hooking rate than did J hooks. The lowest mortality rates were for the J/Blocker hook (45%) baited in the head, circle hooks (18%) baited in the tail, and 38% for blockers baited in the tail.

Grover et al. (1997, unpublished) conducted a 12 day hooking mortality study comparing 3/0 vs 5/0 circle hooks for chinook < 26 in captured off of San Francisco during July, 1997. The baits (anchovy) were fished in the standard "head-down" mooching presentation. A total of 170 chinook were held in onboard holding tanks for 4 days. The circle hook mortality was estimated to be 31% for mooching with bait threaded through the head. A high proportion of the fish captured were hooked in the gill and gullet area.

Alaska: No marine recreational hooking studies of chinook or coho have been conducted in Alaska. Bendock and Alexandersdottir (1993) used radio tracking to examine hooking mortality of maturing chinook hooked and released by sport anglers in the Kenai River. Over a three-year period, 446 adult chinook were tracked for up to five days. Overall mortality was 7.6%. Injury location was the factor most associated with mortality. Vincent-Lang et al. (1993) examined hooking mortality for sport-caught and released coho in the estuarine area of Little Sustina River. The reported mortality was 69%, although coho in this area were still adjusting to their return to freshwater and may have been vulnerable to additional stress.

Section 4.0: Recreational Salmon Fisheries- Recent Reviews

Stohr and Fradenburg (1986) provided a Delphi assessment of chinook and coho salmon hooking mortality for Washington based fisheries sport and commercial fisheries that set hooking mortality rates for both legal and non-legal fish at 30% for barbed single hooks and 26% for barbless single hooks. In 1987, the CTC (1987) reviewed available hooking mortality information for chinook captured in marine recreational salmon fisheries and set hooking mortality rates at 20%-30% for legal size chinook and 20% - 30% for sub-legal size chinook. WDF et al. 1993), compared recent results for recreational fishing with those recommended by Stohr and Fraidenburg (1986). They recommended mortality rates be reduced to a weighted average of 8% for both coho and chinook combined, based on the results of Gjernes (1990), NRC (1991), and Gjernes (1993). For chinook alone, they recommended using 10% for legal-size fish and 20% for sublegal fish.

In 1994, the Salmon Technical Team (SST) of the Pacific Fishery Management Council (PFMC) reviewed recent findings from several studies on hooking mortality and recommended that hooking mortality rates for PFMC sport fisheries be reduced from the 31% rate being used at that time (26% plus 5% non-landed mortality) to 15%for both chinook and coho (SST 1994). The 15%rate was an average of mortality measured over four days for coho (6%) and chinook (10%) in the NRC studies plus an additional 5% for drop-off mortality and 2% for other factors. PFMC (1994) accepted the new rate of 8% for hook and release mortality for coho and chinook, and the additional 5% for drop-off mortality, but not the associated mortality increment. This resulted in a revised rate of 13% in PFMC recreational fisheries. Subsequent to this recommendation, Grover (1994) reported that hooking mortality rates for northern California sport fisheries might be as high as 60%. This raised concern that the NRC studies conducted to that date may not be applicable in other areas. Gear and method was identified as an important factor determining mortality rates, and NRC was requested to conduct more studies.

In 1997, the CTC (1997) conducted a review of hooking mortality for sport fisheries under PSC jurisdiction. They recommended using hooking mortality rates for chinook captured in marine recreational fisheries that were specific for two size categories:

> 33 cm	12.3%
< 33 cm	32.2%

The CTC recommended applying the rate for the larger size category, because second-ocean and older fish are "by far the most common age classes encountered in PSC recreational fisheries" (CTC 1997). The CTC (1997) also developed estimates for drop-off mortality based on actual estimates of the unlanded encounter rates and explicit assumptions for the drop-off mortality rate. The CTC (1997) recommended using an additional mortality increment for drop-off mortality in recreational fisheries that is fishery-specific:

SEAK	3.6%
Puget Sound	14.5%
Oregon	2.7%

For fisheries where specific data are not available, the CTC (1997) recommended using the average of these rates (6.9%), or rates from a comparable fishing area, to estimate escaped encounters and predator losses.

Section 5.0: Discussion and Recommendations

The purpose of this report was to outline current knowledge regarding hooking mortality as it relates to coho and chinook salmon captured in marine recreational fisheries in British Columbia. Based on the results of studies conducted from California to Alaska, it is evident that hooking mortality can be quite variable for the same salmon species captured on similar gears in different areas. Hooking mortality for coho and chinook in marine recreational fisheries varies from 5% to over 30% along the Pacific coast. Hooking mortality is influenced by a wide range of factors including fishing technique, fish species, fish size, fish behaviour and aggressiveness, food availability, fish abundance, stage of maturity, temperature/season, depth of capture, hook size and type, and angler skill in playing, landing, and releasing (Muoneke and Childress 1994). The CTC (1997), in its review of the main factors contributing to differences in the hooking mortality rates for chinook derived from agency reviews of recent studies, identified the most important as being 1) hook type, 2) fishing technique, 3) size differences, and 4) adjustments for drop-off and associated mortality. The many variables potentially affecting hooking mortality may make optimal management of a particular species and water bodies difficult using regional-level management regulations (Muoneke and Childress 1994). A paragraph regarding hooking mortality by Wilson (1997) eloquently describes the difficulties associated with selecting appropriate hooking mortality rates for recreational fisheries:

"...estimating hook and release mortality in sport fisheries is a complex process. Some causes of possible mortality are difficult to investigate, while others will change through the fishing season or vary between years. This means that the results of studies for one species, period, fishing area or fishing technique may not be applicable even for very similar fisheries. Similar studies can result in a range of estimates of mortality, and a good deal of professional judgement and familiarity with the fishery in question is required to choose those studies to apply in a particular circumstance. Choosing an estimate of hook and release mortality to use for management purposes usually involves a consensus among professionals, which is to say that choosing almost any estimate of hook and release mortality for a particular fishery will cause an argument..."

With respect to British Columbia marine recreational chinook and coho fisheries, current hooking mortality rates are set at 10% for coho and 15% for chinook. These rates are not gear or method specific, do not include a drop-off or long-term mortality component, and are applied equally to all fisheries coastwide. From a fishery impact (e.g. modelling of exploitation rates) perspective, this approach is probably not appropriate, as the actual impacts of catch and release fishing may be underestimated or overestimated with these rates depending upon the fishery in question. As with findings recently noted by the NRC (1998) in

U.S waters, hooking mortality rates in marine recreational fisheries in British Columbia are likely dependent upon the gear, the period, and the method of fishing used. In general, less active forms of fishing (e.g. mooching), appear associated with higher hooking mortality rates, while more active forms of fishing (e.g. trolling) appear associated with lower hooking mortality rates. To accurately characterize mortalities in British Columbia marine recreational fisheries, it will be necessary to measure encounters by gear and method type and apply a mortality rate appropriate to the gear and methods actually being used. Where there are no estimates of hooking mortality rates for a particular gear, or where local variations of fishing method may lead to different rates, it may also be necessary to conduct additional studies to establish appropriate values.

Recommendations

1) For British Columbia marine recreational fisheries, hooking mortality for coho and chinook is likely dependent upon the gear and methods used. Region-wide hooking mortality rates are not appropriate.

2) For British Columbia marine recreational fisheries, assumed hooking mortality rates for coho and chinook assessment/management modelling should take into account gear and method differences.

3) Assessment programs should be developed to quantify gear and method-specific hooking mortality rates for coho and chinook in major British Columbia marine recreational fisheries where information is lacking. Creel surveys should routinely collect information on the fishing methods being used in specific fisheries.

4) Assessment programs should be considered to address the delayed effects of hooking mortality on long-term survival and ability of released coho and chinook to return and spawn successfully.

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Table 1. Recent studies showing the range of hooking mortality rates obtained for Chinook salmon captured on marine recreational sport fishing gear in British Columbia, Washington, Oregon, and California.

Study	Species	Location	Gear	Method	Hook Type	Holding Time	Captures	Deaths	Mortality Rate
NRC 97	Chinook (adult)	Oregon	Flasher +Lure/Bait	Trolled	4/0 single barbless	3-4 hrs	35	0	0%
NRC 97	Chinook (adult)	Oregon	Flasher +Lure/Bait	Trolled	4/0 single barbless	3-4 hrs	59	1	2%
NRC 97	Chinook (adult)	Oregon	Flasher +Lure/Bait	Trolled	4/0 - 3/0 tandem barbless	3-4 hrs	18	0	0%
NRC 97	Chinook (adult)	Oregon	Flasher +Lure/Bait	Trolled	4/0 - 3/0 tandem barbless	3-4 hrs	104	3	3%
NRC 97	Chinook (adult)	Oregon	Flasher +Lure	Trolled	6/0 Siwash barbless	3-4 hrs	26	2	8%
Gjernes 90	Chinook 35-98 cm	Southern BC	Flasher +Lure	Trolled	4/0 tandem barbed	24-72 hrs	152	15	10%
Grover 94	Chinook 28-28 "	California	Hardbait	Trolled	-waived	24-48 hrs	674	74	11%
Grover 93	Chinook 28-28 "	California	Hardbait	Trolled	-waived	24-48 hrs	755	91	12%
Grover 96	Chinook 28-28 "	California	Hardbait	Trolled	-waived	24-48 hrs	189	25	13%
Gjernes 90	Chinook >62 cm	Southern BC	Flasher +Lure	Trolled	4/0 tandem barbed	24-72 hrs	?	?	14%
Gjernes 91	Chinook (adult)	Northern B C	Cut-Plug Herring	Trolled-Mooched	5/0 and 3/0 tandem barbed	24 hrs	100	15	15%
NRC 97	Chinook (adult)	Oregon	Rotating Herring	Mooched	3/0 circle barbless	3-4 hrs	13	0	0%
NRC 97	Chinook (adult)	Oregon	Rotating Herring	Mooched	4/0 - 3/0 tandem barbless	3-4 hrs	88	8	9%
NRC 91	Chinook 31-101 cm	Washington	Rotating Herring	Mooched	1/0 - 2/0 tandem barbless	24-48 hrs	67	6	9%
NRC 97	Chinook (adult)	Oregon	Threaded Herring	Mooched	4/0 circle threaded barbless	3-4 hrs	7	1	14%
NRC 97	Chinook (adult)	Oregon	Rotating Herring	Mooched	4/0 single barbless	3-4 hrs	86	13	15%
Grover 96	Chinook 28-28 "	California	Whole Anchovy/Herring	Drift Mooched	4/0-5/0 Circle Hooks/Tail	48 hrs	?	?	18%
Grover 97	Chinook 28-28 "	California	Whole Anchovy/Herring	Drift Mooched	3/0-vs 5/0 Circle Hooks barbless	48 hrs	170	53	31%
Grover 96	Chinook 28-28 "	California	Whole Anchovy/Herring	Drift Mooched	4/0-5/0 Hooks/Blackers/Tail	48 hrs	?	?	33%
Grover 95b	Chinook 28-28 "	California	Whole Anchovy/Herring	Drift Mooched	2/0-5/0 J-Hooks	24-36 hrs	217	80	37%
Grover 96	Chinook 28-28 "	California	Whole Anchovy/Herring	Drift Mooched	4/0-5/0 Hooks/Blackers/Head	48 hrs	?	?	45%
Grover 93	Chinook 28-28 "	California	Whole Anchovy/Herring	Drift Mooched	4/0-5/0 single J-hooks	24-48 hrs	632	368	58%
Grover 94	Chinook 28-28 "	California	Whole Anchovy/Herring	Drift Mooched	4/0-5/0 single J-hooks	24-48 hrs	861	395	68%
Grover 95	Chinook 28-28 "	California	Whole Anchovy/Herring	Drift Mooched	4/0-5/0 single J-hooks	24-48 hrs	512	373	73%

Table 2. Recent studies showing the range of hooking mortality rates obtained for Coho salmon captured on marine recreational sport fishing gear in British Columbia, Washington, Oregon, and California.

Study	Species	Location	Gear	Method	Hook Type	Holding Time	Captures	Deaths	Mortality Rate
NRC 97	Coho (adult)	Oregon	Rotating Herring	Trolled	4/0 - 3/0 tandem barbless	3-4 hrs	35	1	3%
NRC 91	Coho 34-62 cm	Washington	Rotating Herring	Trolled	1/0 - 2/0 tandem barbless	24-48 hrs	145	10	7%
Gjernes 92	Coho (adult)	Northern B C	Cut-Plug Herring	Trol-Mooched	3/0 tandem barbed	24 hrs	100	18	18%
NRC 97	Coho (adult)	Oregon	Rotating Herring	Trolled	4/0 single barbless	3-4 hrs	105	14	13%
Gjernes 90	Coho 30-55 cm	Southern B C	Flasher +Lure	Trolled	all hook types combined	24 hrs	83	6	7%
NRC 97	Coho (adult)	Oregon	Flasher +Lure/Bait	Trolled	4/0 - 3/0 tandem barbless	3-4 hrs	144	19	13%
NRC 97	Coho (adult)	Oregon	Flasher +Lure/Bait	Trolled	4/0 single barbless	3-4 hrs	129	18	14%
NRC 97	Coho (adult)	Oregon	Flasher +Lure	Trolled	6/0 Siwash barbless	3-4 hrs	77	13	17%
NRC 97	Coho (adult)	Oregon	Rotating Herring	Mooched	3/0 circle barbless	3-4 hrs	34	1	3%
NRC 97	Coho (adult)	Oregon	Rotating Herring	Mooched	4/0 - 3/0 tandem barbless	3-4 hrs	77	10	13%
NRC 97	Coho (adult)	Oregon	Threaded Herring	Drift Mooched	4/0 circle threaded barbless	3-4 hrs	30	7	23%
NRC 97	Coho (adult)	Oregon	Rotating Herring	Mooched	4/0 single barbless	3-4 hrs	75	18	24%
Cox-Rogers 97	Coho (adult)	Northern B C	Cut-Plug Herring	Motor Mooched	4/0 tandem and single barbless	24 hrs	242	63	26%

Figure 1. Recent studies showing the range of hooking mortality rates obtained for Chinook salmon captured on marine recreational sport fishing gear in British Columbia, Washington, Oregon, and California (data from Table 1).

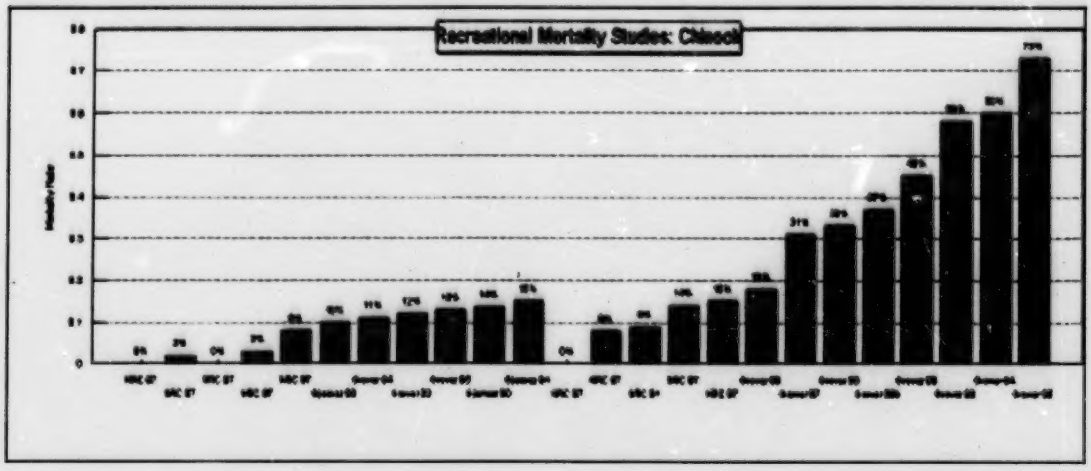

Figure 2. Recent studies showing the range of hooking mortality rates obtained for Coho salmon captured on marine recreational sport fishing gear in British Columbia, Washington, Oregon, and California (data from Table 2).